

UTC Microturbine CHP Product Development and Launch

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Carrier

DOE and ORNL
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January 2004 DOE/CETC Microturbine Applications

Agenda



Microturbine/Absorption Chiller CHP System

- ◆ Technology goal and plan
- ◆ UTC/CTC Strategic Alliance Agreement
- ◆ Exhaust heat driven, double effect chiller
- ◆ CHP system integration and validation
- ◆ PureComfort™ 240 is launched by UTC Power

Recycling Waste Heat for Power

- ◆ Pathway to 40% microturbine
- ◆ Organic Rankine Cycle economics and validation
- ◆ C200/ORC system
- ◆ PureCycle™ 200 to recycle waste heat nearing launch

Conclusions

- ◆ UTC Power is impacting CHP marketplace

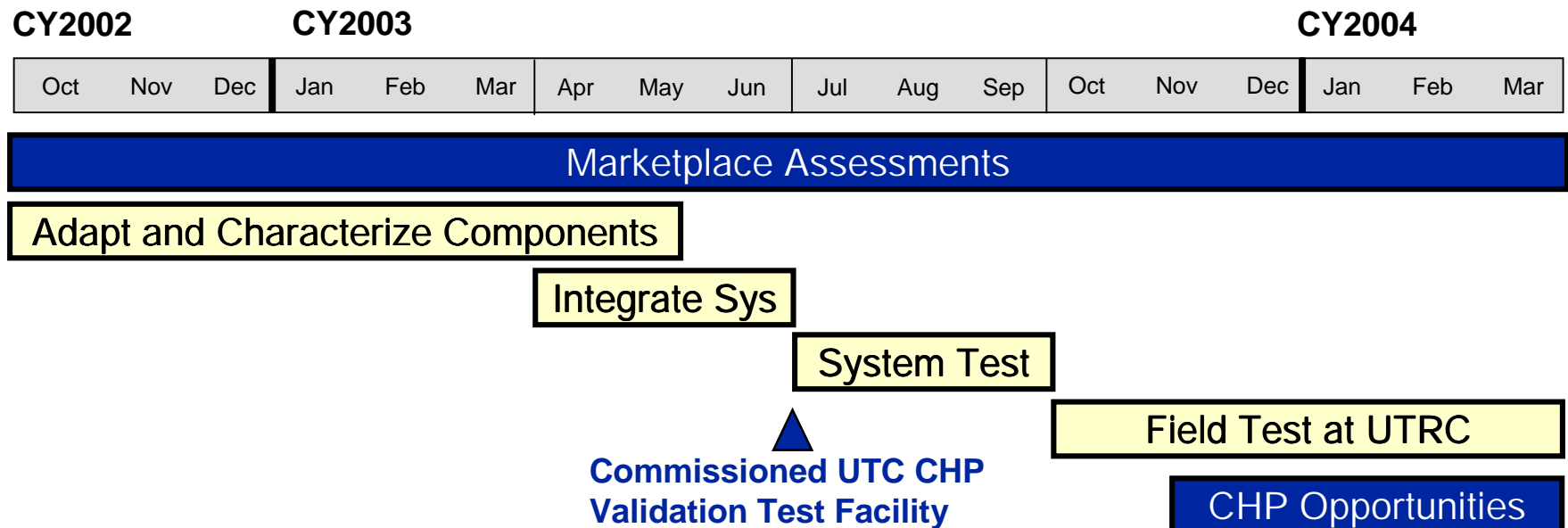


Microturbine CHP System Goal and Approach



- ◆ Develop and demonstrate an market-driven microturbine/absorption chiller CHP system

- ◆ Guidance from marketplace never ends
- ◆ Adapt affordable, leading-edge CHP components
- ◆ Integrate 4 CTC C60 microturbines and a Carrier double effect absorption chiller, and demonstrate CHP system performance



The October, 28, 2002 news release contained the following:

“The strategic alliance between UTC and Capstone is a long term agreement to integrate, sell, and service microturbine-based **combined heat and power solutions** for commercial buildings.”

“UTC and Capstone intend to **build on key product, technology, and channel strengths** of the companies, including those of UTC’s Carrier Corporation – the leading manufacturer of heating, ventilation, and air conditioning systems.”

“The agreement covers North America and most of Europe.”

“As part of the alliance agreement, UTC has committed to purchase a 4.9 percent stake in Capstone.”



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“Begin with the end in mind” S. Covey **- Microturbine/Chiller CHP system**



CHP system integration of -

4 x C60 Microturbines



+

Double Effect Carrier Chiller



- can meet many building needs:

Electric Load

- Lighting
- Ventilation
- *Refrigeration*
- *Space Cooling*

+

Cooling Load

- *Space*
- *Subcooling*

Heating Load

- *Space*
- *Water*

Direct-Fired Carrier Chiller Converted for Waste-Heat



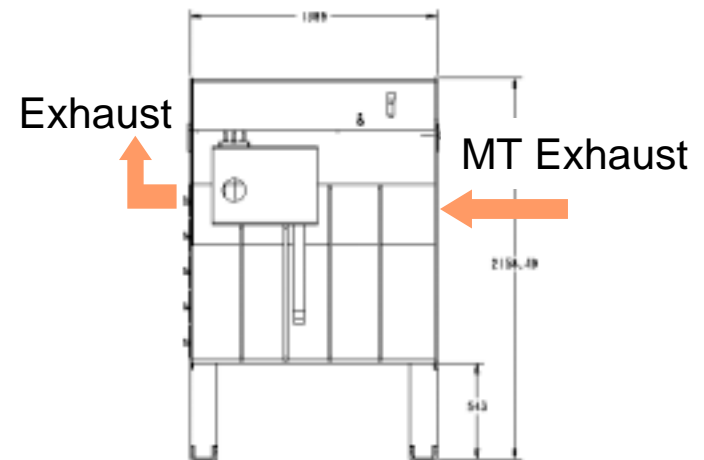
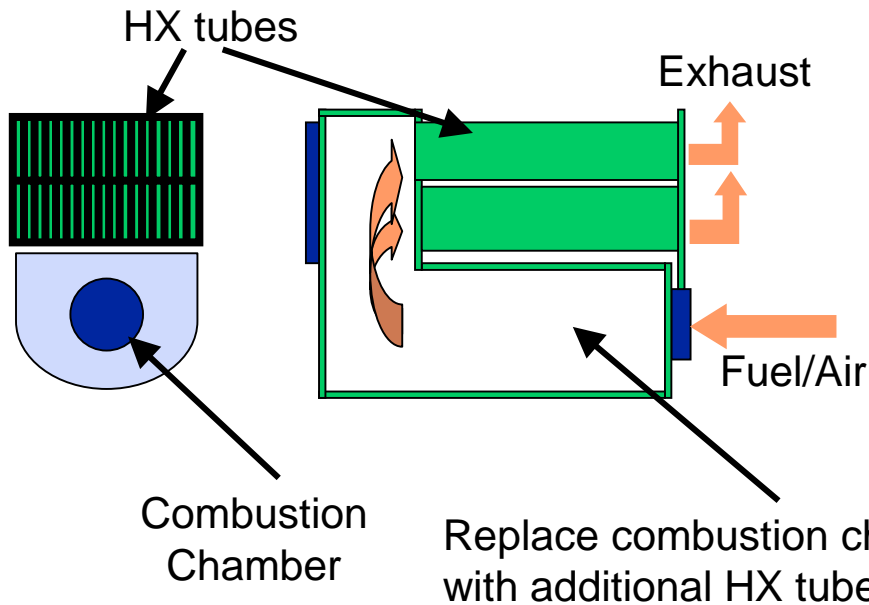
16DN Chiller/Heater



CHP Chiller/Heater

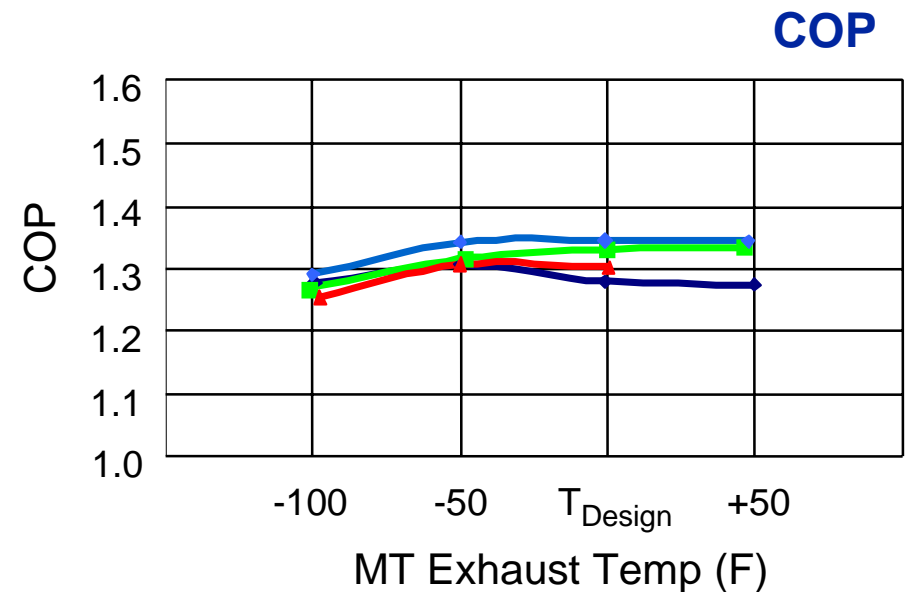
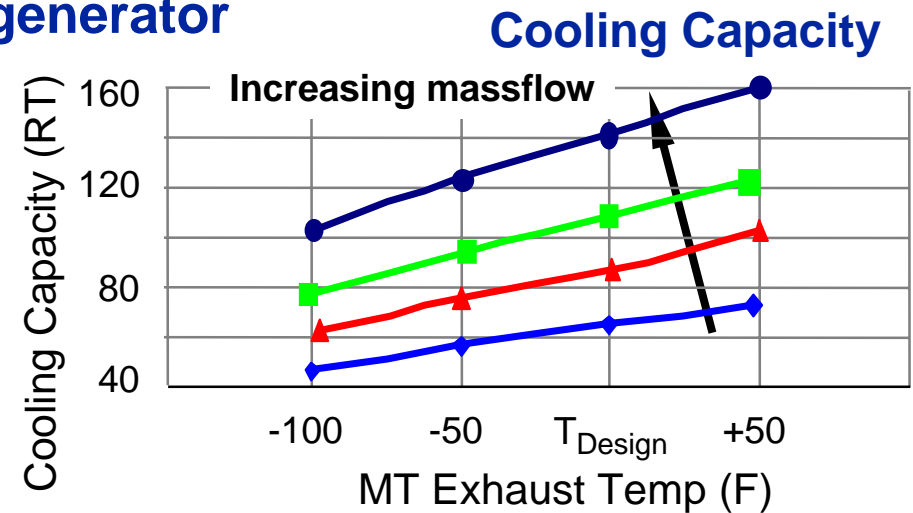
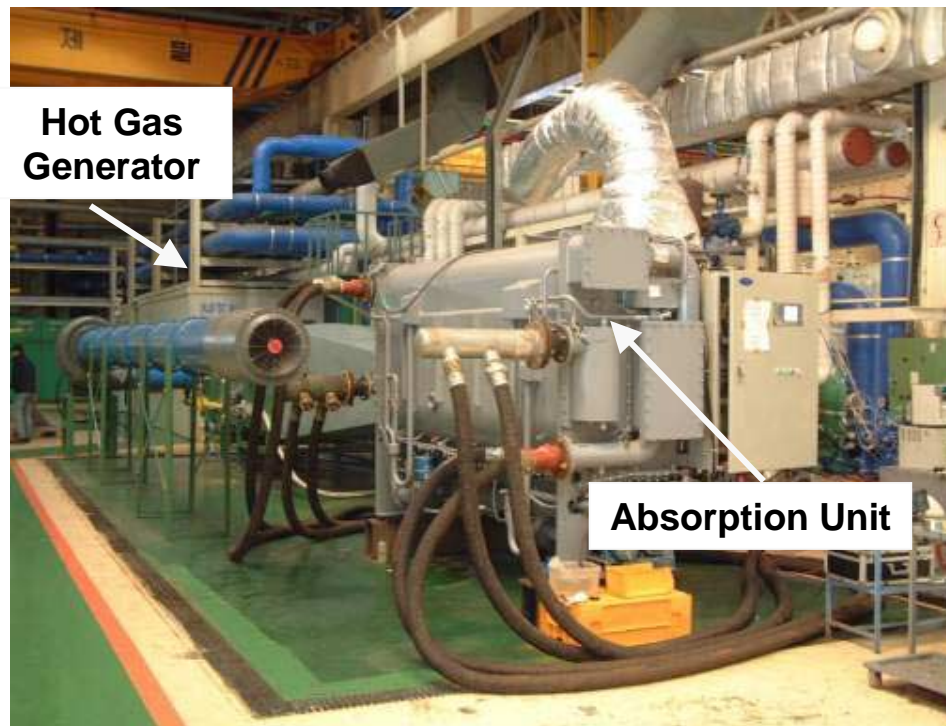


Modified HX



Waste Heat Carrier Chiller Achieves 1.3 COP

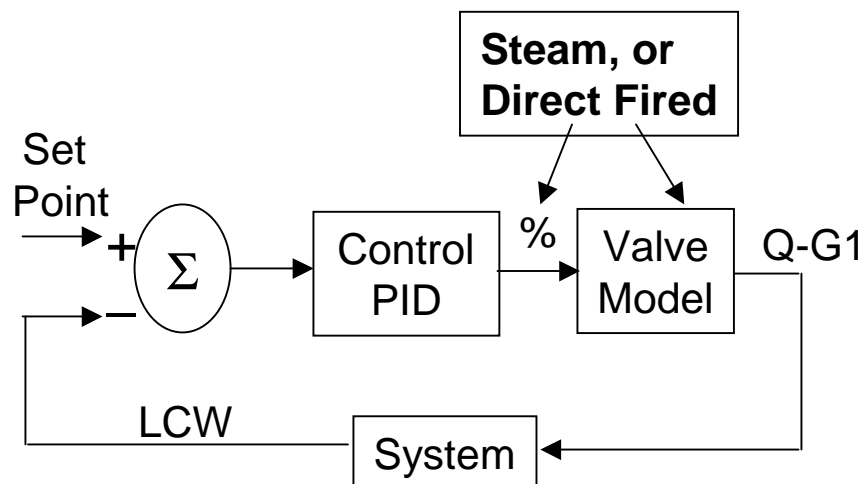
Chiller s/s performance with hot gas generator



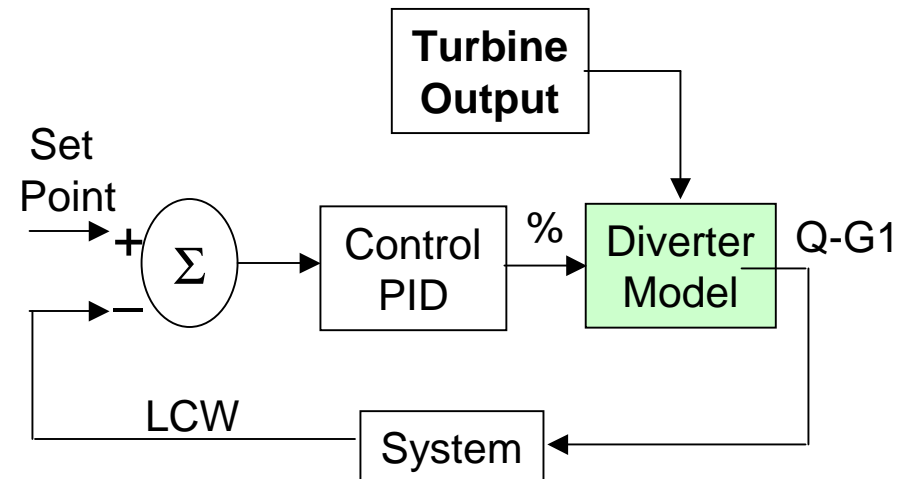
Waste-Heat Diverter Used to Control Chiller Output

Substitute diverter valve control for fuel valve control

Existing Product



CHP Product



Diverter Valve – used for capacity control

- Air seal blower to insure zero leakage
- Electric actuator used to set position

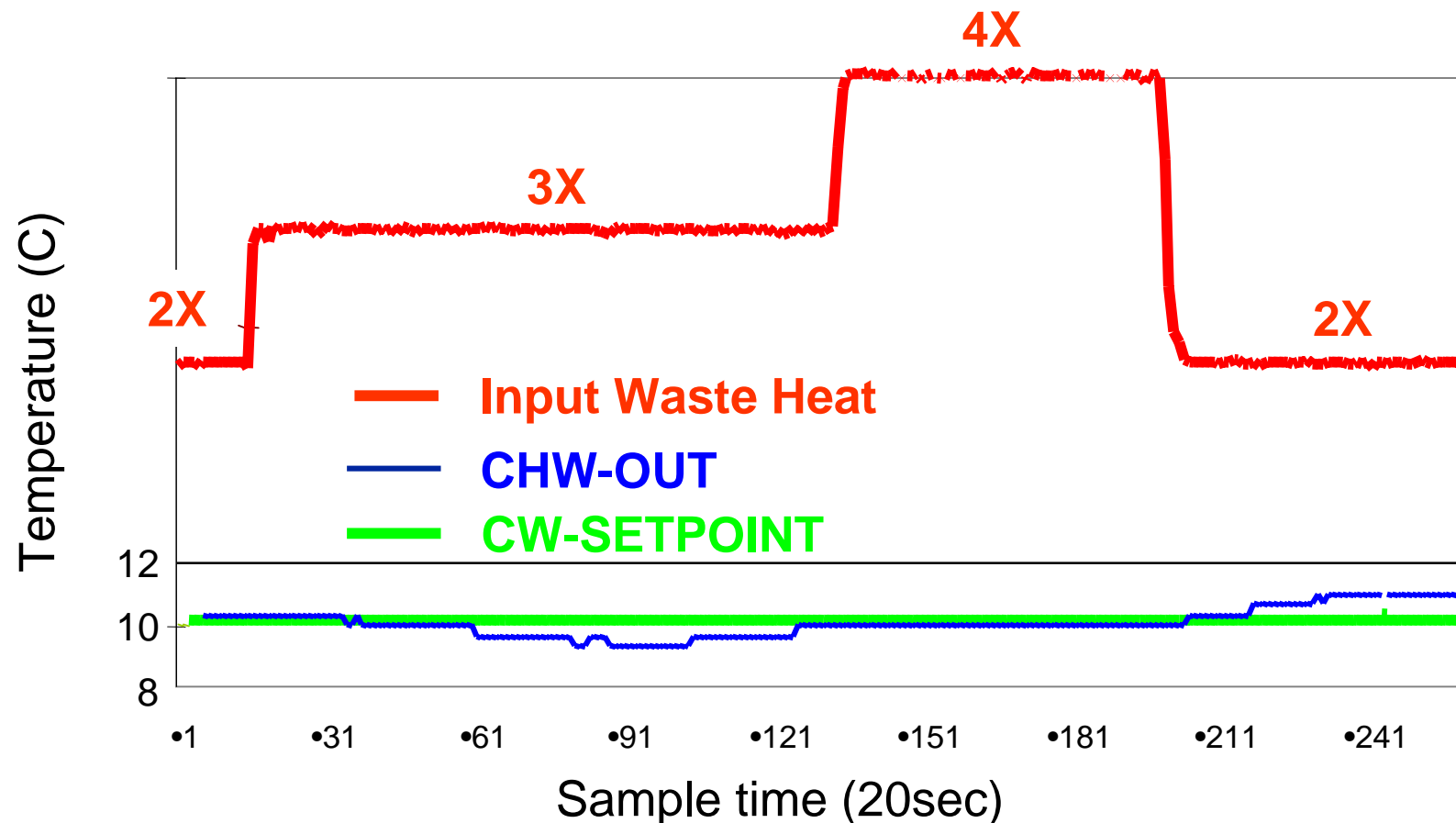


Chilled-Water Setpoint Held During Waste-Heat Transients



Transient Heat Source Test with hot gas generator

- ◆ Chilled water leaving temperature maintained to within 1.8 F



CHP System Risks Identified and Mitigated



No residual single point criteria failure modes

- ◆ System controls ensure that highest severity failure modes do not result in health or safety risk
 - For example, must not allow fuel to accumulate in duct
- ◆ Highest Risk Priority Number failure modes driven down by system design, control strategies, or testing.

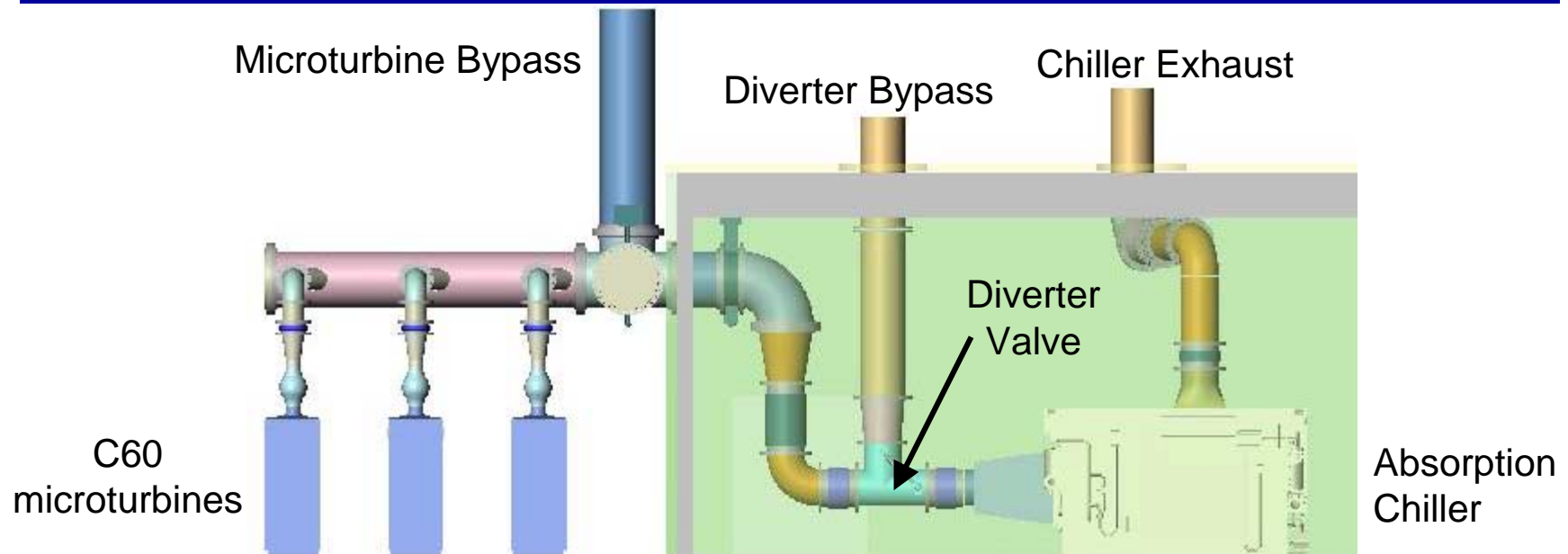
Failure Modes From FMEA						
Likelihood	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		Severity				



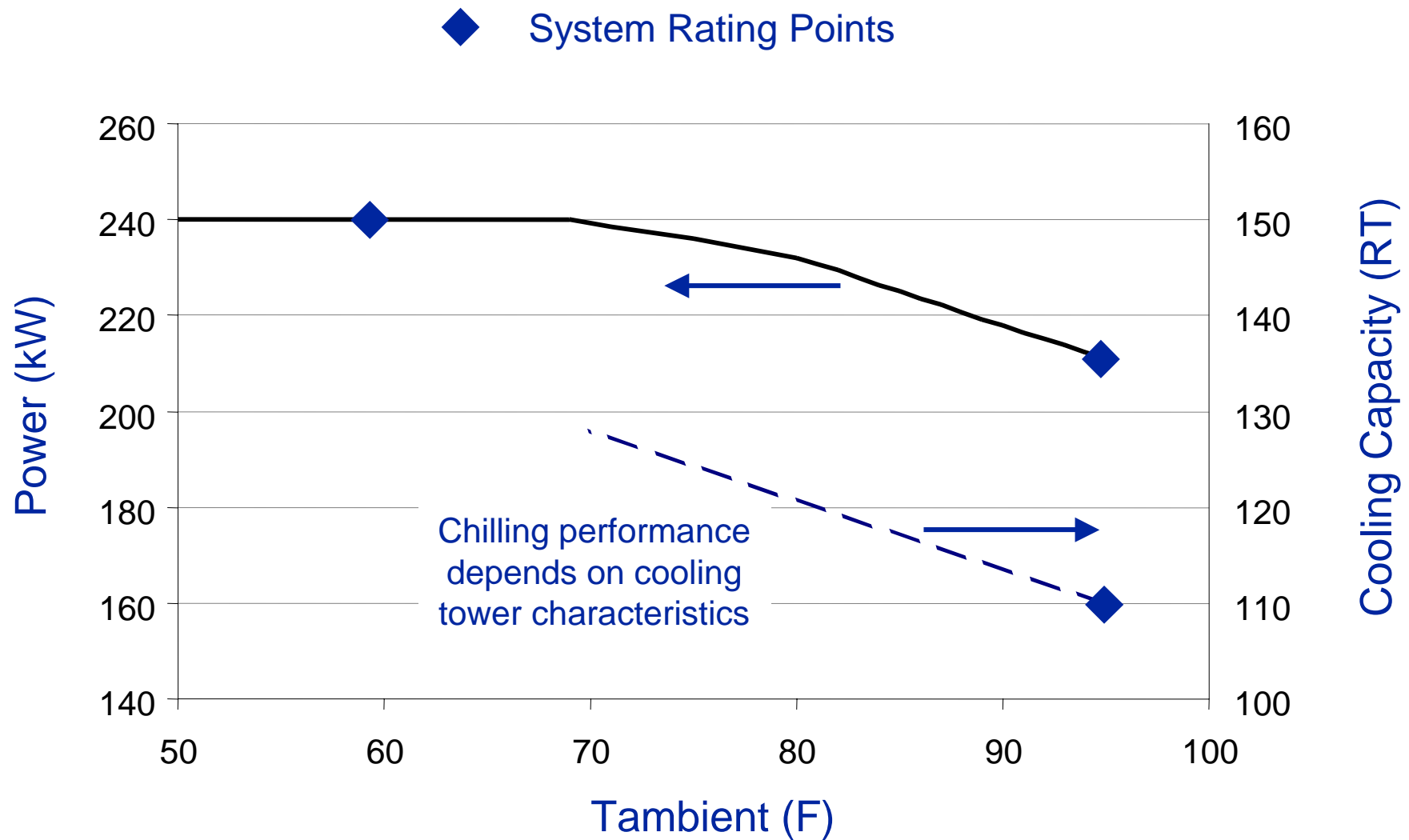
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C60/Absorption Chiller System in CHP Validation Test Facility



C60/Absorption Chiller System Performance





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UTC Power PureComfort™ 240 Launched



Clean power and comfort inside,
no matter what the conditions outside.



Advanced Microturbine System Goal and Approach

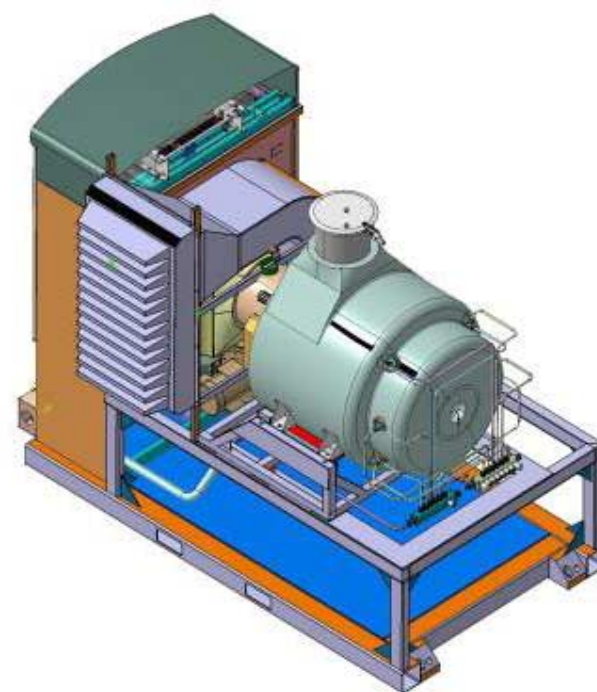


DOE Advanced Microturbine System Goals

- ◆ Electrical efficiency = 40%
- ◆ $\text{NO}_x < 7$ ppm on natural gas
- ◆ 11,000 hour between major overhaul
- ◆ System cost ~\$500US/kW

UTRC Goal and Approach

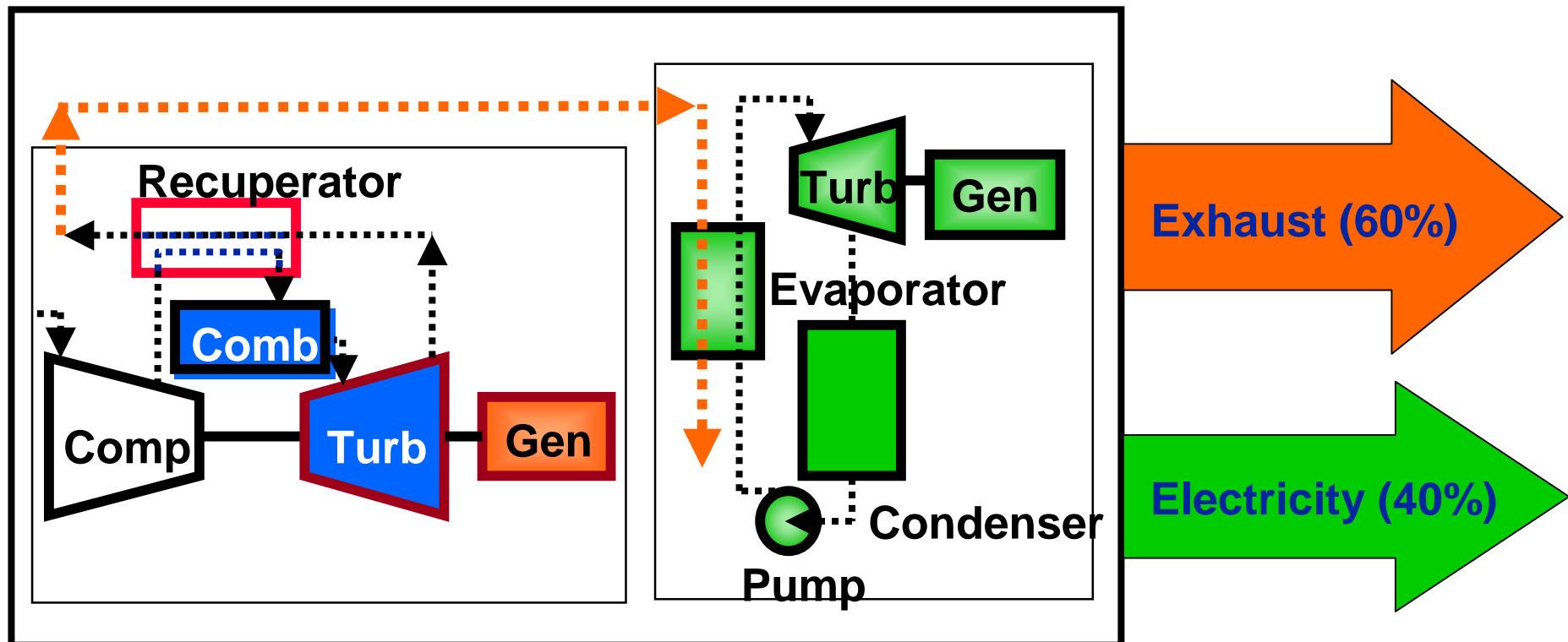
- ◆ Affordably increase Capstone C200 microturbine from 33% to 40% electrical efficiency with $\text{NO}_x < 7$ ppm



Consistent Approach to Advanced Microturbine System



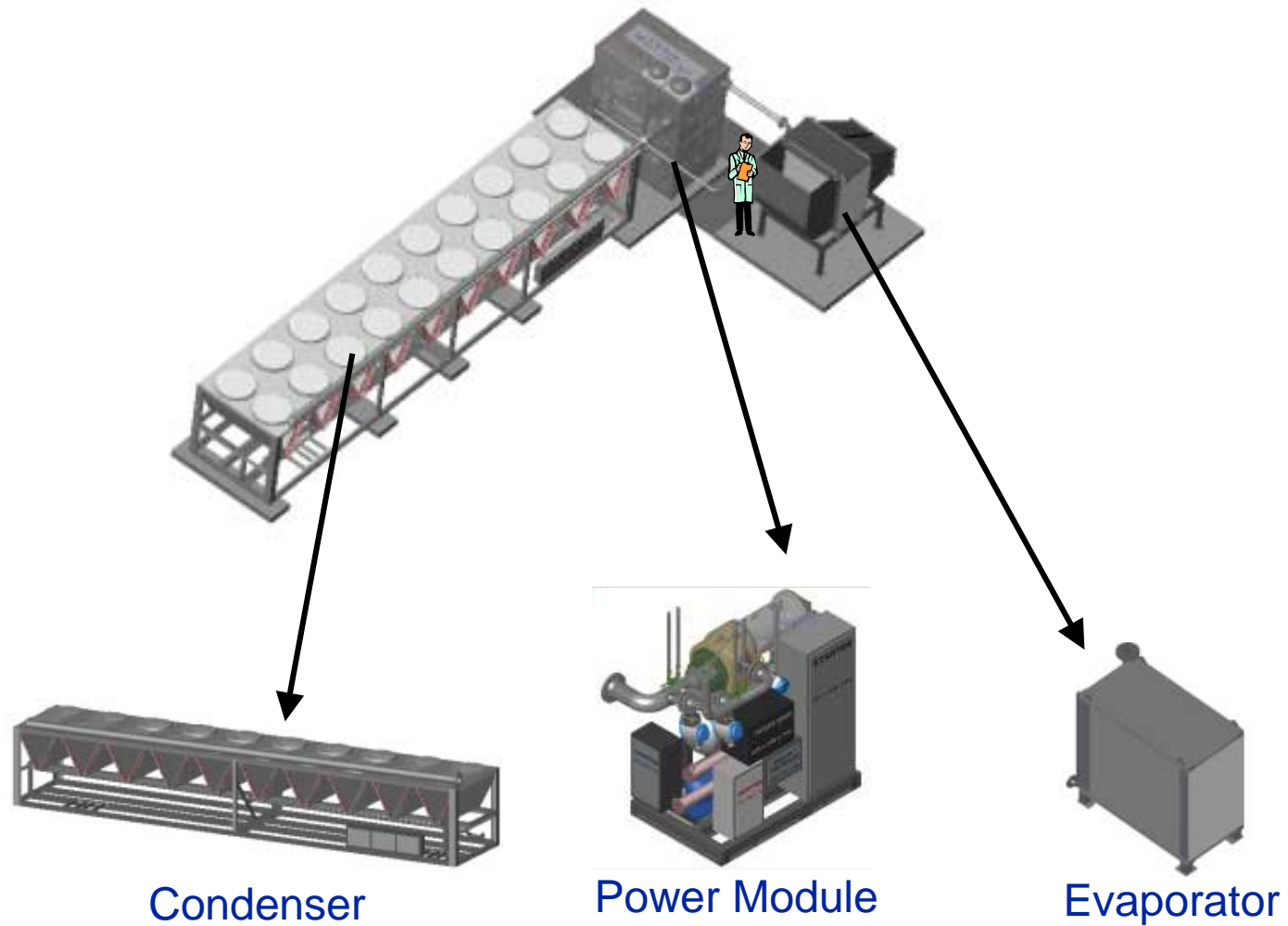
UTRC sustains recycling exhaust energy into power as the affordable means to high efficiency



ORC System Consists of 3 HVAC Modules



HVAC leverage limits cost

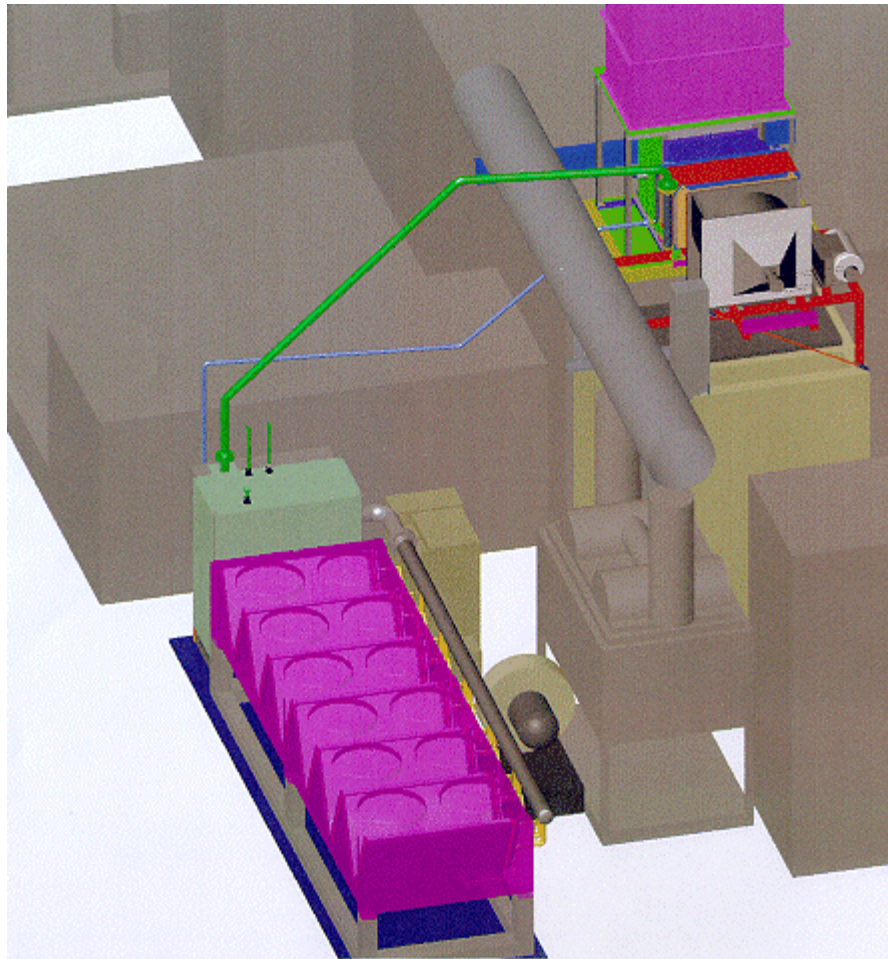


100 kW ORC Engineering Prototype Driven by 1.5MW IGT



Integrated to portion of IGT exhaust

- ◆ Delivered 100kW of electrical power to UTRC grid
- ◆ Demonstrated cavitation-free operation
- ◆ Validated transient control strategy



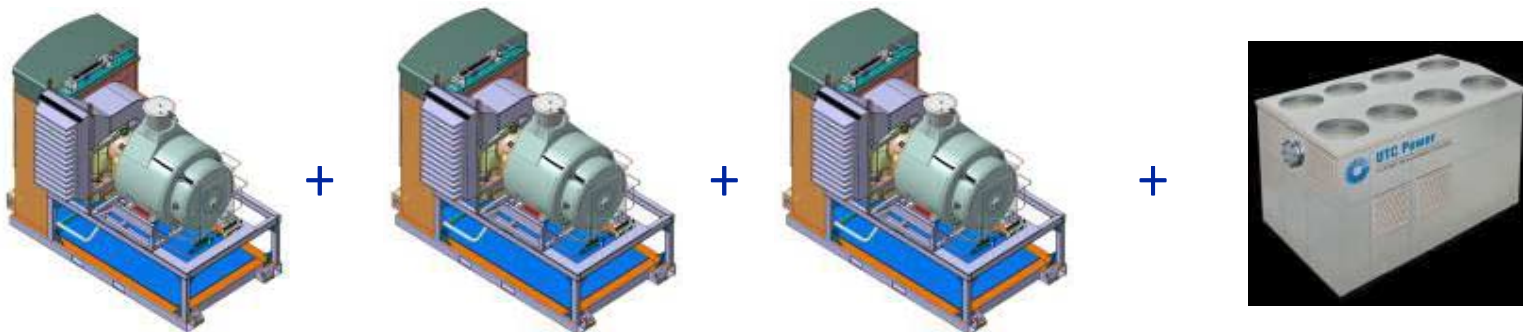


Advanced Microturbine System Next Steps



Integrate C200/ORC system and demonstrate 40% electrical efficiency

- ◆ Add HW heat exchanger to produce thermal output
- ◆ Substitute water-cooled condenser
- ◆ Mechanical and control integration with C200
- ◆ Test integrated system at steady state and transient conditions



$$\begin{aligned}\text{System Efficiency} &= (P_{C200} + P_{ORC})/E_{\text{fuel}} \\ &= \text{Eff}_{C200} \times (P_{C200} + P_{ORC})/P_{C200} \\ &= 33\% \times (600 + 128)/600 \\ &= 40\%\end{aligned}$$

Waste Heat is Everywhere



Landfill Flare



Gas Compression



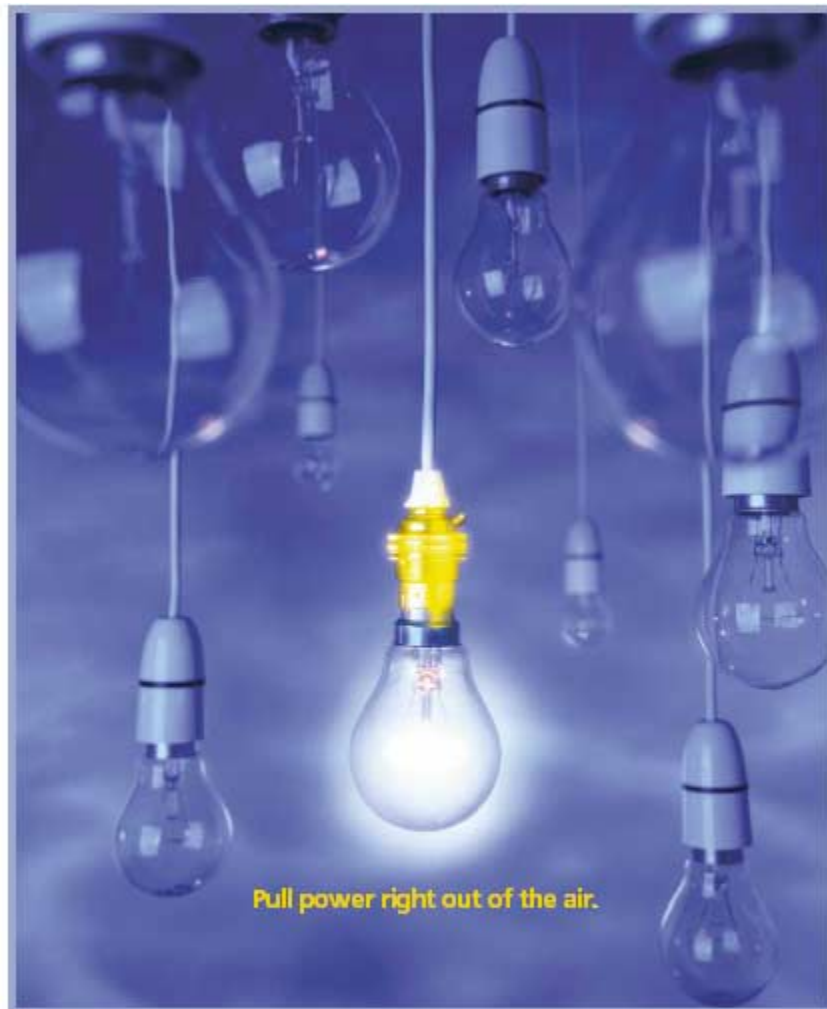
Landfill Engine



Industrial Processes

Annual U.S. industrial waste > 4 quadrillion BTU (160 GW)

UTC Power PureCycle™ 200



Pull power right out of the air.

Turn **Waste Heat** into **Electricity**

– with the **PureCycle™ Zero Emission Power System.**

The clean way to profit from waste heat.

If you're generating heat, you can create electricity. And maybe you already are. But even if you have a waste heat-to-energy system in place, you're not using your resources to their fullest potential. Because now you can use the PureCycle™ power system, a unique heat-to-electricity solution from UTC Power.

The PureCycle™ power system is a closed-cycle process that uses waste heat to generate electrical power. Driven by a simple evaporation process, the entire system is enclosed, which means it produces no emissions. The only product is electricity. And the fuel – waste heat – is free, so there's no cost to power the system once it's installed.

Flexible, site-compatible design.

The PureCycle™ system can be used with any waste heat above 500°F (gaseous) or 200°F (liquid or vapor), whether it comes from engines, flares or industrial sources. The PureCycle™ power system is also surprisingly compact which makes the system moveable. If, for whatever reason, you wish to use another heat source, the system can be disengaged and relocated.

Built and supported by energy experts.

While the PureCycle™ power system is relatively new, it draws upon decades of United Technologies Corporation innovation and expertise.



PureCycle™ Power System features:

- ▼ **Waste-heat powered** – The PureCycle™ power system is designed to be used with engines, turbines, industrial processes or flare waste heat. In each case, you're leveraging current resources, and the fuel is free.
- ▼ **No system emissions** – In some cases the PureCycle™ power system can qualify for emissions credits and help lower net emission/MWh of the host site.
- ▼ **Safe working fluid** – Your operations and the environment are protected through the use of a non-flammable, non-ozone-depleting working fluid which is sealed within the system.
- ▼ **Low generation cost** – Generation costs of the PureCycle™ power system are lower than natural gas fueled reciprocating engines. In addition, the system is easily installed in many cases, resulting in attractive payback periods.
- ▼ **Fully automated, self contained** – PureCycle™ power systems are designed to run unmanned – 24/7/365. And because the systems are sealed, they're inherently weather-resistant, so there's no need for protective housing.
- ▼ **Low operating cost** – Maintenance is minimal, and the system is designed for long life.



UTC is on Pathway to Impact CHP Marketplace



Technology development and demonstration launched as an integrated microturbine/absorption chiller-heater CHP system

- ◆ PureComfort™ 240
- ◆ CHP system fuel utilization >70% in cooling mode
- ◆ Combines leading edge technology of CTC and UTC
- ◆ PureCycle™ 200 affordably recycles waste heat into power
 - Pathway for 40% electrical efficiency

UTC products and plans have great public benefit

- ◆ Expand customer choice for reliable, affordable electrical and thermal energy
- ◆ Delivers the energy streams with less fuel consumption and pollutants
- ◆ UTC/DOE collaboration is having a direct impact on the marketplace by enabling new products

UTC Power Sales Contacts

